as well ask, how can a crystal grow without sensation. Nor has that great naturalist failed to perceive these extreme consequences of this extension of the biological jurisdiction, for he seeks to escape them only by pushing it still farther, and proclaiming the animation of all material atoms, even of the lowest orders—*die Atom-Seele.* It seems far simpler, as well as more correct, to recognize in protoplasm a true chemical substance, but one whose properties constitute the fundamental element of life.

Such a conclusion is no longer the bold speculation that it would have been pronounced a few years ago, and this paper could not be more fittingly concluded than with the words of Professor O. C. Marsh, uttered in 1877, that "if we are permitted to continue in imagination the rapidly converging lines of research pursued to-day, they seem to meet at the point where organic and inorganic nature become one. That this point will yet be reached, I cannot doubt."

——:o:——

THE REPTILES OF THE AMERICAN EOCENE.

BY E. D. COPE.

REMAINS of *Batrachia* are rare in North American formations later than the Permian. There are two or three species of *Stegocephali* known from the Trias, above which formation that order is not known to extend in any country. No Batrachians have been obtained from the Jurassic or Cretaceous systems excepting from the top of the latter, in the Laramie. Here occur the salamandrine genera *Scapherpeton* and *Hemitrypus* Cope. A single specimen of a frog from the Eocene is mentioned below, and then we miss them until the Loup Fork or Upper Miocene, where *Anura* and salamanders have been found.

The vertebral column and part of the cranium of a probably incompletely developed tailless Batrachian, were procured by Dr. F. V. Hayden, from the fish shales of the Green River epoch, from near Green River City, Wyoming. They are not sufficiently characteristic to enable me to determine the relation of the species to known forms. It is the oldest of the order *Anura* yet discovered, the fossil remains of the known extinct species having been derived from the Miocene and later formations of Europe.

The Eocene period, was, of the divisions of the Tertiary, the

most prolific of reptilian life. It is true that the orders of reptiles which characterized the Mesozoic periods no longer existed. The *Dinosauria* had perished from the land; the *Ichthyopterygia*, *Sauropterygia* and *Pythonomorpha* no longer inhabited the sea, and the *Pterosauria* had disappeared from the air. What occasioned the remarkable change in reptilian life at the close of the Laramie epoch can only be surmised. During that time the principal land population of North America consisted of *Dinosauria*, of which there were many species and genera. With the opening of the Puerco Eocene, these huge beasts had entirely disappeared, and a population of small and medium sized Mammalia took their place. The comparative feebleness of the new comers precludes the idea that they assaulted and drove out or killed the *Dinosauria*, or that they devoured their food and left them to starve. The only probable hypothesis must suppose that a change of climate ensued, either in a depression of the temperature, or in a desiccation of the atmosphere, which greatly reduced the amount of vegetable life. The large *Dinosauria* would perish from lack of food, where smaller animals could live. That there was a general desiccation at the beginning of the Eocene period in central North America is indicated by topographical evidence. It was towards the close of the Laramie that the elevation of the Rocky mountains was completed, and their greatest effect in retaining the clouds and rains, must have been apparent. Nevertheless, this effect could not have continued, since the later Eocene and Miocene epochs were rich in forests and animal life.

The Eocene reptiles were not a new creation, nor a new evolution, but a remnant of the types that had coëxisted with the monarchs of life during previous ages. We must except from this statement the serpents, which first appear in numbers at this time, only one cretaceous species having been found by Dr. Sauvage, in France. The crocodiles, tortoises, and lacertilians represent orders already abundant in the Mesozoic faunæ. Their decadence in Central North America did not commence until the Miocene period, when the crocodiles and nearly all the tortoises disappeared. From the Loup Fork or Upper Miocene, only a few traces of lizards have been obtained, and snakes were apparently not very numerous. On the eastern coast regions, crocodiles existed, and tortoises were more numerous during the Miocene period; but here also they were less abundant and varied than during the Eocene.

LACERTILIA.

Of lizards I have obtained the remains of a half dozen of species, but none of them in a complete state of preservation. Professor Marsh has been more fortunate, as he described from his material from the Bridger beds, twenty-one species.[1] He arranges these under five generic heads, as follows: *Thinosaurus* Marsh, five species; *Glyptosaurus* Marsh, eight species; *Xestops* Cope (1873, *Oreosaurus* Marsh, not Peters), five species; *Tinosaurus* Marsh, two species; and *Iguanavus* Marsh, one species. As Professor Marsh does not give us any clue to the affinities of these forms, they cannot be further considered here. In Lieutenant Wheeler's Survey Report[2] I have pointed out that the dermal scuta and a few other fragments which I obtained in the Wasatch beds of New Mexico, were probably referable to the *Placosauridæ*, a family created by Gervais to receive certain *Lacertilia* of the Eocene of France. To this family no doubt some of the species described by Marsh from the Bridger horizon are to be referred.

The Puerco epoch is characterized by the presence of the suborder *Choristodera*, of which one genus, *Champsosaurus* Cope, holds over from the Laramie Cretaceous. These were large and medium sized animals, somewhat resembling Crocodiles. They have, according to Lemoine, who has discovered them in France, ambulatory limbs, adapted for swimming.

OPHIDIA.

The snakes of the Eocene are not very numerous as to species.

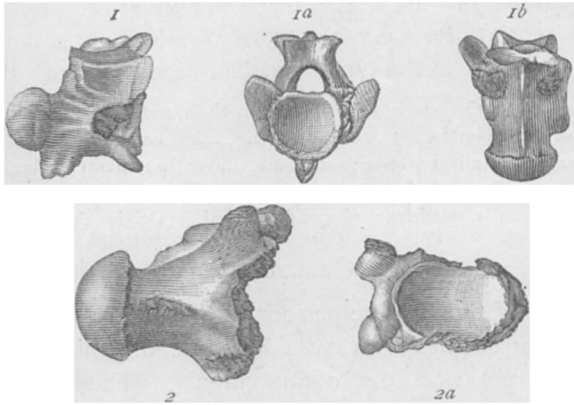


FIG. 1.—*Palæophis littoralis* Cope, from New Jersey. (Original.) FIG. 2.—*Palæophis halidanus* Cope, from New Jersey. (Original.)

[1] American Journal of Science and Arts, 1871, June, and October, 1872.

[2] Vol. IV, pt. II, p. 42, pl. XXXII, fig. 26–36.

The first known American species (*Palæophis littoralis* and *P. halidanus*) were determined by myself from New Jersey specimens. None have been procured from beds lower than the Bridger, and in that formation I found a single form. Professor Marsh described five species.

Species of the genus *Palæophis* occur in the Eocene of England. They are supposed by Owen to be related to the Peropodous or Boæform families. They reached as large a size as the largest existing snakes. Other smaller Eocene species are said to have similar affinities.

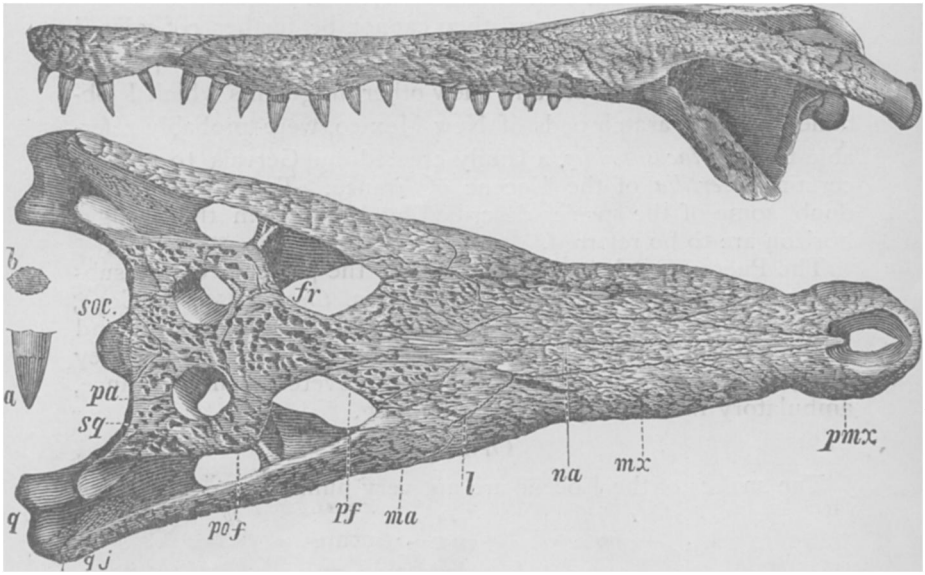


FIG. 3.—Skull of *Crocodilus acer* Cope, from Utah, nearly one-third natural size, lateral and superior views. FIGS. *a* and *b*.—Lateral view and section of a maxillary tooth. *Pmx*, premaxillary bone; *mx*, maxillary; *na*, nasal; *l*, lachrymal; *pf*, prefrontal; *ma*, malar; *fr*, frontal; *pof*, post-frontal; *pa*, parietal; *soc*, supraoccipital; *sq*, squamosal; *q*, quadrate; *qj*, quadratojugal. (Original.)

CROCODILIA.

The fauna of the Eocene periods of the United States included a number of species of *Crocodilia*, some of which were represented by great numbers of individuals. They were equally numerous in the Wasatch and Bridger epochs, but none have been found in the Green River formation proper. They are moderately abundant in the Wind River beds, and a species is

known from the Manti beds of Utah. None are known from the Miocene formations east or west of the Rocky mountains, but they are not rare in the marine Miocene of the Atlantic coast. All the species belong to two genera, *Plerodon* Meyer, and *Crocodilus* Linn. One species of the former is found in the Wasatch beds, with three or four species of *Crocodilus*. In the Bridger beds I know of six species of the latter genus.

It is a fact that the American genus *Alligator* is nowhere found in the Tertiary formations of our continent. It is evident that it is a specialized form of *Crocodilus*, which first appeared in Europe in Tertiary times, and subsequently in this country.

CROCODILUS Linn.

The Eocene species of true crocodiles differ much in size and characters, ranging from the *C. heterodon*, which is not larger than an *Iguana*, to the *C. antiquus* and *C. clavis*, which rival the existing species of the East Indies.

The species are divided into two sections, which are distinguished by the form of the frontal bone. In the one it is thin, and has low lateral olfactory crests. Such species are as yet only known from the Wasatch formation. They are the *C. grypus* Cope and *C. wheeleri* Cope. The species of the second section have massive frontal bones with strong lateral olfactory crests. The *C. heterodon* of the Wasatch belongs here; also the *C. elliottii* of the Bridger, and the *C. clavis* of the Washakie basin. The frontal bones of several of the species are unknown. The species may be also distinguished by the sculpture of their teeth, some having the crowns grooved or channeled, and others having them smooth or finely lined. Of the former kind are *C. subulatus* Cope, *C. acer* Cope and *C. sulciferus* Cope; all the other species come under the second head. The *C. squankensis* Marsh, from the Eocene of New Jersey has the enamel peculiarly rugose. A peculiarity of the composition of the crowns of some of the species has been noticed, on account of which I proposed a genus, *Thecachampsa*. In this type the crown is composed of concentric hollow cones, one within the other. I have not been able to separate the crowns of the recent crocodiles into such bodies, and they are generally too thin to display more than a very few such layers, were they so separable. This character was first observed in some species of the Atlantic Coast, *e. g.*, *C. antiquus* Leidy, and

C. squankensis Marsh; and the two Eastern Miocene species, *C. sericodon* Cope (type of *Thecachampsa*) and *C. sicaria* Cope.

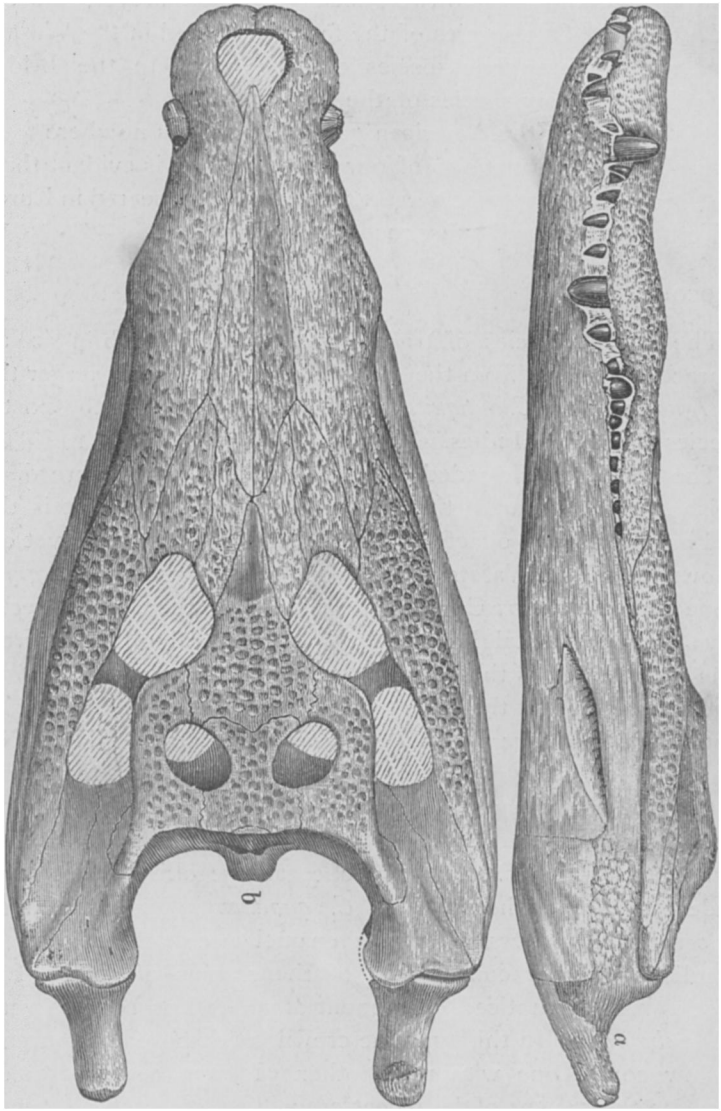


FIG. 4.—*Crocodilus affinis* Marsh, from Wyoming, nearly one-third natural size, lateral and vertical views. (Original.)

The forms of the crowns vary considerably. In nearly all Crocodilia the posterior teeth have short and obtuse crowns; but in *C. heterodon* Cope, this character is carried very far. The

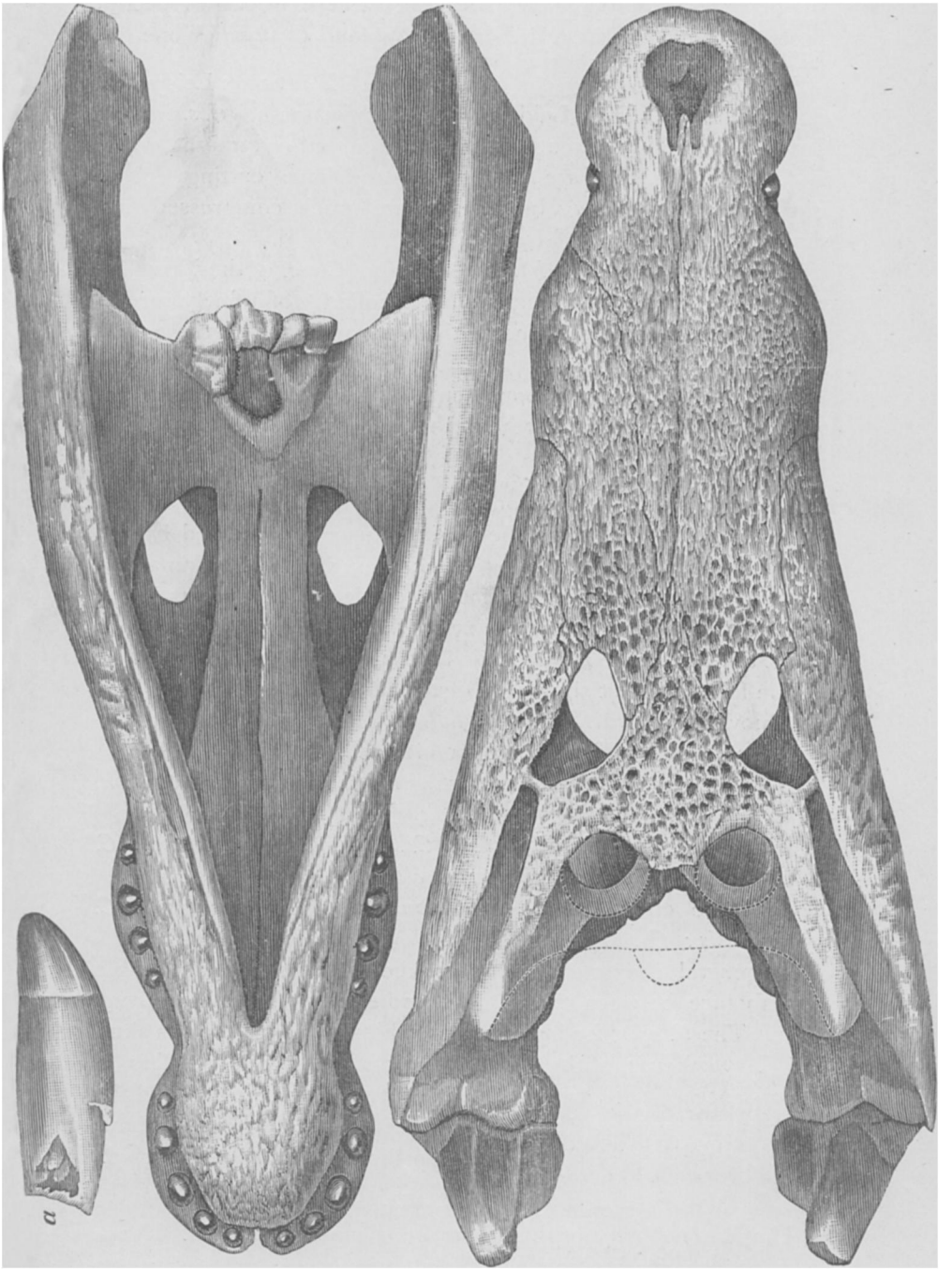


FIG. 5.—Cranium of *Crocodilus clavis* Cope, lacking the occipital bones, from above and below, less than one-eighth natural size. *a*.—A maxillary tooth, one-half natural size. (Original.)

posterior crowns are oval, bean-like bodies, with a median line from which fine incised lines radiate.

Species with obtusely conic crowns are *C. antiquus* Leidy; *C. clavis* Cope; *C. elliottii* Leidy; and *C. affinis* Marsh. *C. subulatus* Cope has the crowns acutely conic and curved or straight, while in *C. acer* Cope, they are compressed and have cutting edges. Finally, in *C. xiphodon* Marsh, they are much compressed and sharp-edged.

The *Crocodilus (Thecachampsa) serratus* Cope, of the New Jersey Eocene, presents the remarkable peculiarity of a finely serrate ridge along the middle line of the front and back of the neural spines of the vertebræ.

In *C. heterodon* the osseous scuta of the back are articulated together by suture, as in some of the alligators.

PLERODON Meyer.

This genus only differs from *Crocodilus* in the presence of two large teeth in each jaw in the position usually occupied by the single so-called canine tooth. It includes the *P. rateli*, an abundant species in the French Miocene. I detected a species in the Wasatch formation of New Mexico, the *P. sphenops* Cope. It is about the size of the alligator, and has a narrow muzzle.

The following list shows the distribution of the Eocene crocodiles now known:

Puerco epoch. Three species undetermined.

Wasatch epoch. *Crocodilus wheeleri, C. grypus, C. heterodon, C. acer.*

Bridger epoch. *C. subulatus; C. sulciferus; C. xiphodon; C. polyodon; C. affinis; C. elliotti; C. clavis.*

Claiborne epoch (marine). *C. antiquus; C. fastigiatus; C. squankensis; C. serratus.*

In general characters, so far as known, there is considerable resemblance between the Eocene and existing species of *Crocodilus*. The *C. acer*, for instance, resembles in the form of its skull the *C. americanus*, of the West Indies and Mexico, but differs in the absence of the strong convexity of the frontal bone, and the more strongly grooved teeth. In general, the recent species have more pronounced cranial ridges than those of the Eocene period.

TESTUDINATA.

The Eocene forms of this order are of unusual interest. I have seen sixteen species from the Wasatch formation, and thirty-two

from the Bridger and Washakie. Of these, six are common to the two formations, as indicated by imperfect material, leaving a total of forty-two. Three genera, *Emys*, *Trionyx*, and *? Plastomenus* hold over from the Cretaceous period, while six appear for the first time. Of these, five genera are not known to continue later than the Eocene period. In order to understand their relation to members of the order which lived in other periods, I give a general sketch of the classification of the *Testudinata.*

Three primary divisions of this order are generally recognized. The first of these, the *Athecæ*, includes one living and one extinct genus. It is characterized by the absence of the combined coössification of ribs and skin, which form the carapace of other tortoises, and by the annular shape of the inferior shell or plastron, which has no connection with any other part of the skeleton. In the recent genus *Sphargis* (the leather-back turtle), the skin is filled with small osseous plates, which form by their union a dorsal shield.

The other two suborders have the usual carapace and plastron, but they differ in some curious particulars. The greater number of the tortoises of the southern hemisphere cannot draw their heads into their shells, but throw them round sideways when they wish to protect themselves. As if to compensate for this defect, they have the pelvis united by suture below to the plastron, which insures strength but not elasticity. Then they have a peculiar frontal bone, and an additional scutum of the front of the plastron. This group is called the *Pleurodira.* In North America its species are only known as fossils of the Cretaceous period, and will therefore not be further mentioned here. The group which has characterized the Northern Hemisphere since the beginning of Tertiary time, although some of its members appeared earlier, is the third division of tortoises, the *Cryptodira* of Duméril and Bibron. They draw the head within the shell by a sigmoid flexure of the cervical vertebræ; the pelvis is not coössified with the plastron; the frontal bone reaches the palatine below, and there is no additional scutum of the plastron.

Three prominent divisions or tribes may be recognized among the *Cryptodira*, by the various modes of articulation of the plastron with the carapace. In the first, the breast-plate sends out a few digitations to the edge of the dorsal shield on each side,

but forms no true union with it. These are the *Dactylosterna*.[1] The species are all aquatic, and many of them of marine habitat; they are the least specialized of the order, after the *Athecæ*. In the second tribe or *Clidosterna*, the plastron and carapace are united by a close suture at their edges of contact between the positions of the fore and hind legs; and the plastron in addition, sends upwards, at the armpit and groin, on the inner side of the carapace, a process or abutment, which gives great strength to the union. In this division belong the fluviatile and many land

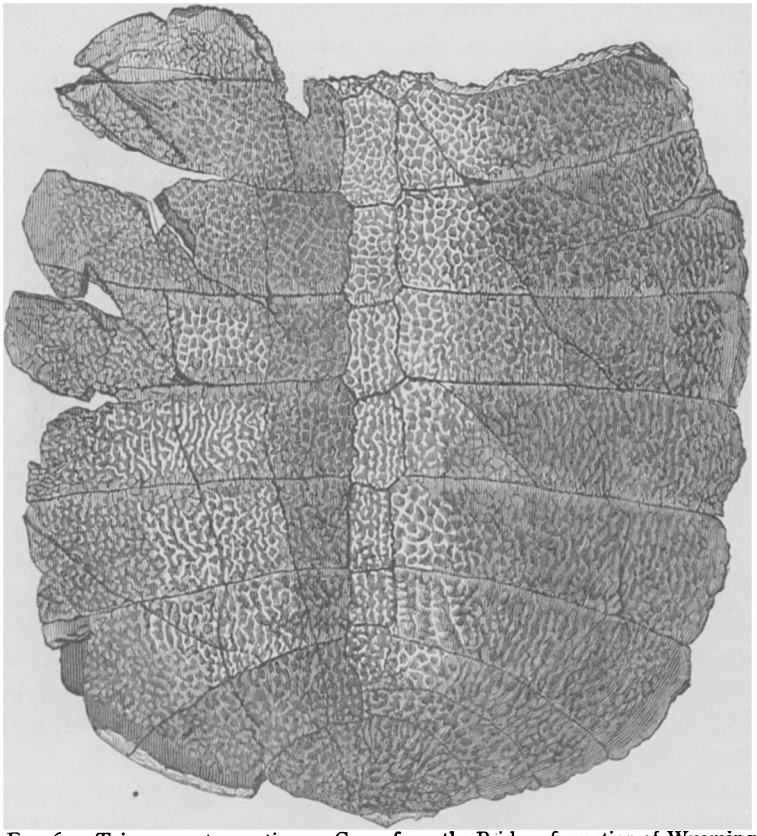


FIG. 6.—*Trionyx scutumantiquum* Cope, from the Bridger formation of Wyoming, one-fourth natural size. (Original.)

tortoises. The third division, or *Lysosterna*, is less abundantly represented by species than the other two. The plastron and carapace are closely joined, but not by suture. Their straight

[1] See Proc. Amer. Philos. Society, 1881, p. 143.

applied edges are separated by a thin layer of cartilage only, and there are no buttresses to strengthen the union. These are the tortoises which close the shell partially or wholly, by a hinge across the middle of the plastron; and they are exclusively inhabitants of the land.

The families of the *Dactylosterna* are the marine turtles (*Chelonïidæ*), the snappers, (*Chelydridæ*), a family which connects the two, (*Propleuridæ*), and the *Trionychidæ* or soft-shelled turtles. The *Propleuridæ* belong to the cretaceous beds only, but the others abound in the Tertiaries.

In the marine Eocene of New Jersey, parts of huge turtles are found, but enough is not yet known of them to assure us to

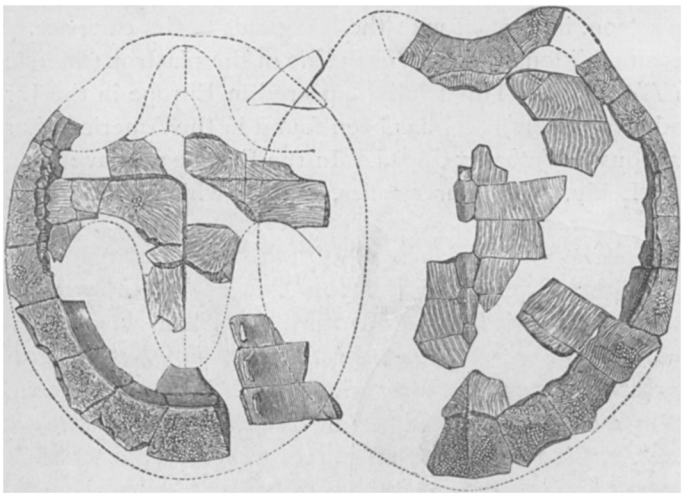


FIG. 7.—*Anostira ornata* Leidy, from the Bridger beds of Wyoming, one-half natural size, superior and inferior views, with section of marginal bone. From Leidy.

what family they belong, except that they are not *Trionychidæ*. The sutures of their shells are very deeply interlocking and splintery. They form the genus *Lembonax* Cope.

In the lacustrine Tertiaries of the West the only families of *Dactylosterna* represented are the *Trionychidæ* and *Chelydridæ*. Although found in the Western rivers at the present time, the *Trionychidæ* are only represented in a fossil state in the Eocene beds. They are unknown in the Miocene of the West, though common in the marine Miocenes of the coast. Species of *Trionyx* are very abundant in the Wasatch and Bridger beds, one of which is represented in the wood cut, Fig. 6. One genus of *Chelydridæ*

occurs in the Bridger formation, the *Anostira* of Leidy (Fig. 7). Its two species differ from the existing snappers in having the marginal bones of the carapace united by suture with the plastron, in which they resemble *Clidosterna*, and in being elegantly sculptured as in the *Trionychidæ*.

The *Clidosterna* are represented by three families, the *Baënidæ*, the *Emydidæ*, and the *Testudinidæ*. The first named family is of much interest, as it displays marked points of resemblance with the *Pleurodira* and the *Chelydridæ*, as well as with *Emydidæ*. Like the first named, it has the additional scuta of the plastron (integulars); like the second, it has the caudal vertebræ concave behind instead of in front, and has an additional row of scuta on the plastron, in contact with the marginals of the carapace. Then it has an additional bone on each side of the plastron (intersternal) as in *Pleurodira*. This family appeared in Europe in the Jurassic period (*Platychelys*), and has been found in the American Laramie Cretaceous (*Polythorax* Cope). In the Eocene we have the genus *Baëna* Leidy, with four species, one of which is figured below

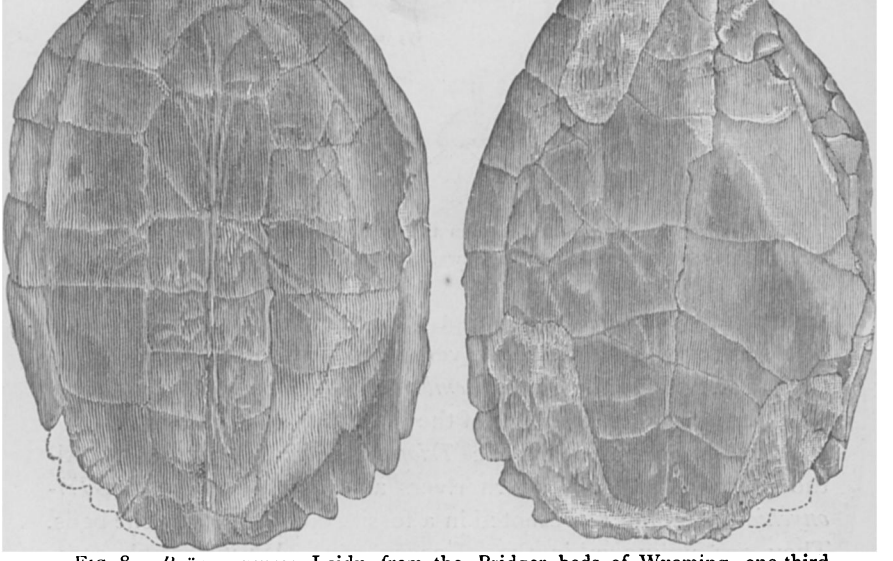


FIG. 8.—*Baëna arenosa* Leidy, from the Bridger beds of Wyoming, one-third natural size. (Original.)

(Fig. 8). Species of *Baëna* range from the size of a red belly (*B. arenosa*) to that of a loggerhead (*B. hebraïca*). The genus is only known in the Wasatch and Bridger.

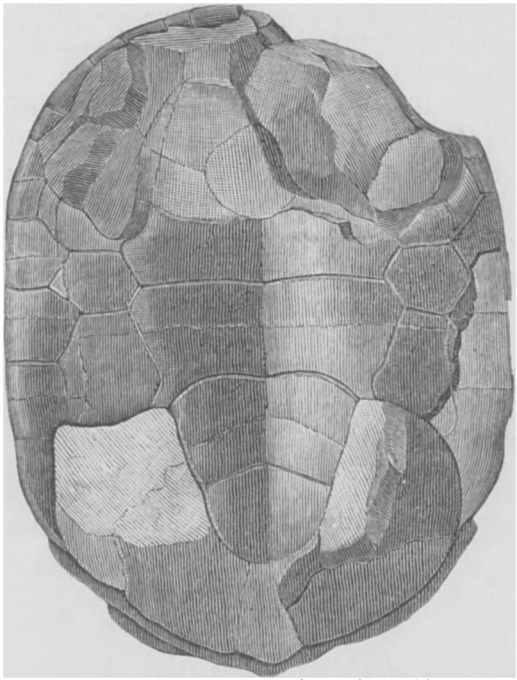


FIG. 9.—*Dermatemys wyomingensis* Leidy, from the Bridger beds of Wyoming. (From Leidy.)

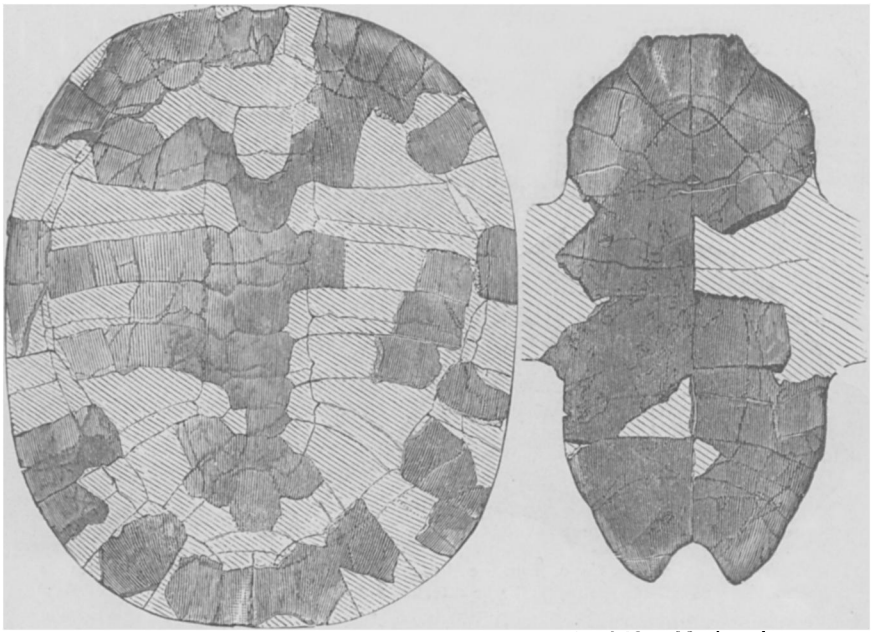


FIG. 10.—*Emys lativertebralis* Cope, from the Wasatch beds of New Mexico, the carapace from above and the plastron from below, one-third natural size. (Original, from Report of Wheeler's Survey, Vol. IV.)

The *Emydidæ* abound in the Eocene beds, and continue in greatly reduced numbers through the Miocene to the present time. But two genera occur in the Eocenes, *Dermatemys* and *Emys*, and these still exist. *Dermatemys* is known by two species, one from the Wasatch, and one from the Bridger (Fig. 9), and by two or three living species from Mexico and Central America. These tortoises have the general appearance of the *Baënæ*, in their narrowed sternal lobes, but they lack the essential characters of that genus, except the intermarginal row of scuta on the sides of the plastron. There are many species of *Emys* in all the Eocene beds. They are all nearly smooth, and of medium size, Fig. 10 represents one of them from the Wasatch bed of New Mexico. Its bones are light and thin; those of *E. shaugnessiana* Cope, are very thick. The surface of *E. septaria* Cope, from the Washakie basin, has delicate radiating lines.

A number of elegantly sculptured species, some of which are of small size, occur in the lacustrine Eocenes. They belong to the genus *Plastomenus* Cope, and they are not yet sufficiently well known to make it clear whether they are *Emydidæ* or not.

One genus of *Testudinidæ* ranges through our Eocenes. This is *Hadrianus* Cope, which only differs from *Testudo* in having two anal scuta instead of one, so far as the carapace is concerned. There are, perhaps, three species, two of which, *H. corsoni* and *H. octonarius*, grow to a large size (Fig. 11–13). They were heavy animals, and represent the earliest of the huge land tortoises of the genus *Testudo*, which still people the Gallapagos and Mascarene islands of the Pacific ocean.

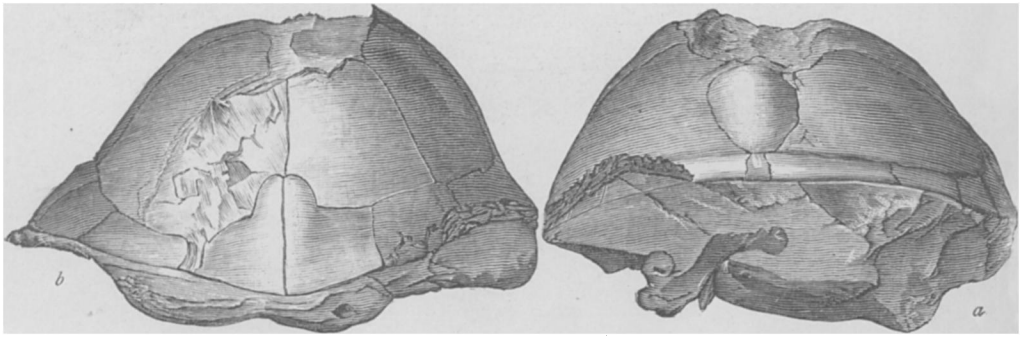


FIG. 11.—*Hadrianus octonarius* Cope, from the Bridger bed of Wyoming, one-eighth natural size extremities *a* anterior, *b* posterior.

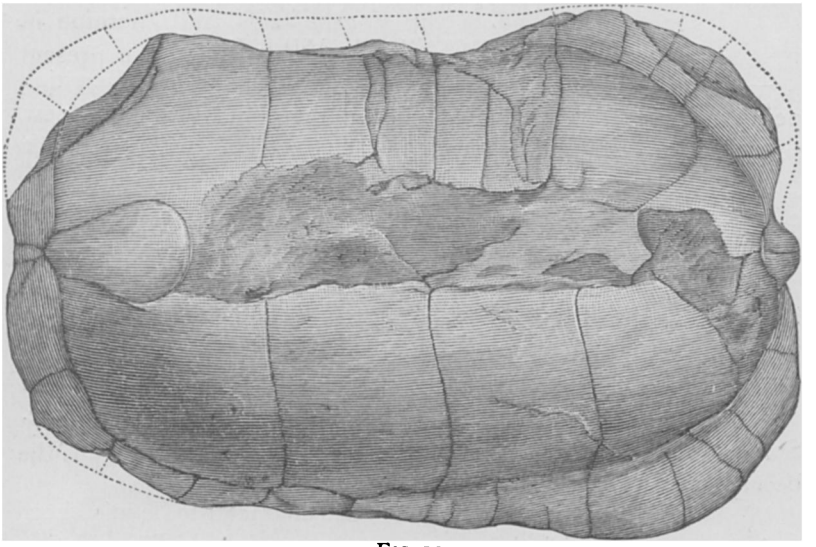
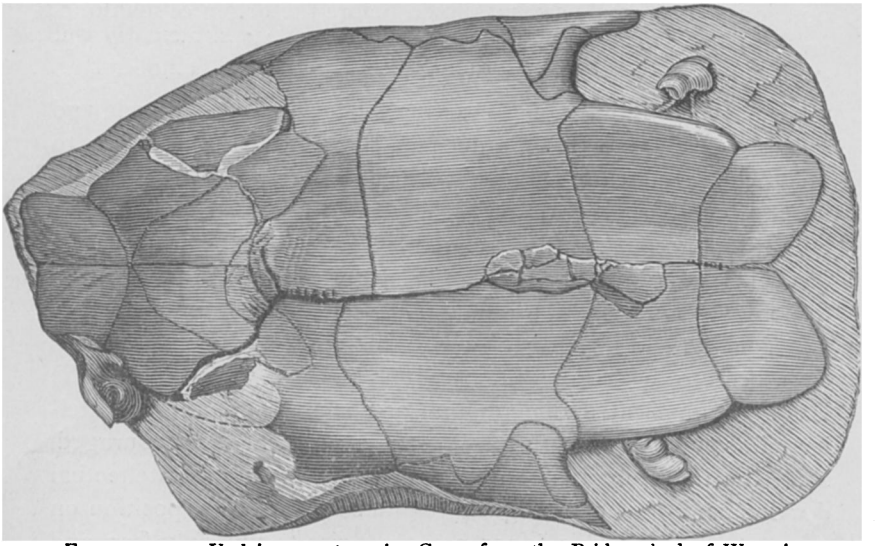


FIG. 12.



FIGS. 12–13.—*Hadrianus octonarius* Cope, from the Bridger bed of Wyoming. Fig. 12.—Superior view. Fig. 13.—Inferior view, one-eighth natural size.

The whole number of species of reptiles thus far discovered in the Eocene of North America, is as follows:

Crocodilia	18
Testudinata	42
Lacertilia	25
Ophidia	6
	91